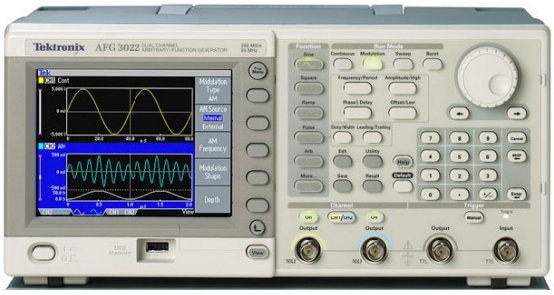

FUNCTION GENERATOR GUIDE

Tektronix AFG3000 Series

Portland State UNIVERSITY

Department of Electrical & Computer Engineering

1 – Introduction

This guide provides instructions for operating the Tektronix AFG3000 Series of function generators.

Features:

- Standard waveforms (sine, square, ramp, triangle, and pulse)
- Arbitrary waveforms with high sampling rates
- Sweep, burst, and modulation (AM, FM, PM, FSK, PWM)
- Large LCD display with on-screen menus for easy setup
- One or two independent output channels
- BNC output connectors
- USB, GPIB, and LAN interfaces

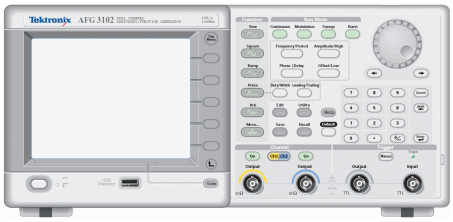

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Table 1: Quick specs for different function generator models in PSU ECE Labs

Model	Output Channels	Maximum Sinusoid Frequency (MHz)	Maximum Sampling Rate (GS/s)	Maximum Output Amplitude (V_{p-p}) into 50 Ω
AFG3021B	1	25	0.25	10
AFG3052C	2	50	1	10
AFG3102	2	100	1	10
AFG3252	2	240	2	5

Note: Channels have a 50 Ω output impedance.

2 – Waveform Shapes

The AFG3000 Series outputs these standard waveforms:

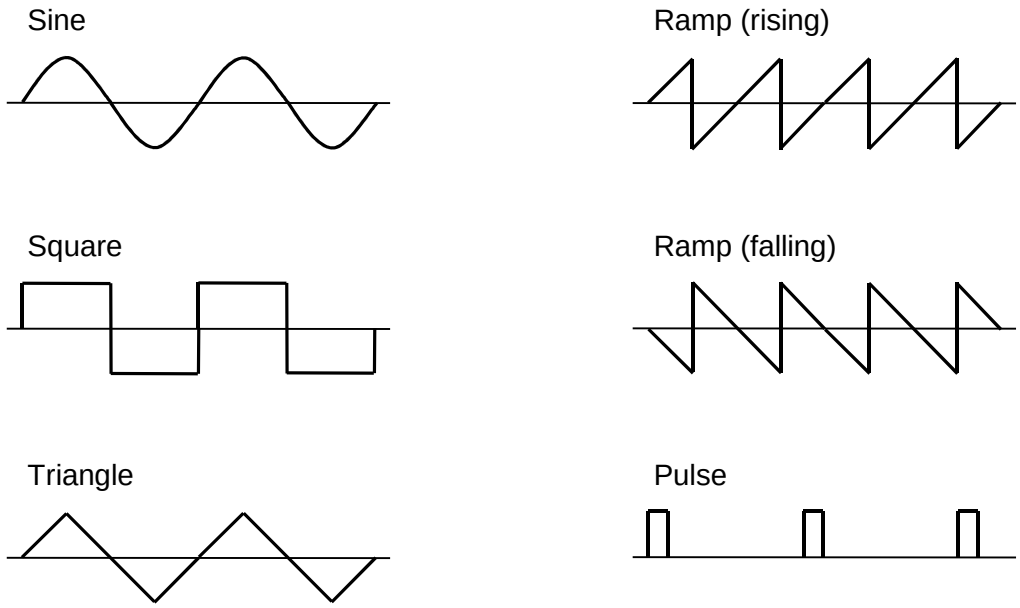


Figure 1: Idealized waveform shapes

In addition, the function generator supports user-defined waveforms of arbitrary shape.

3 – Waveform Characteristics

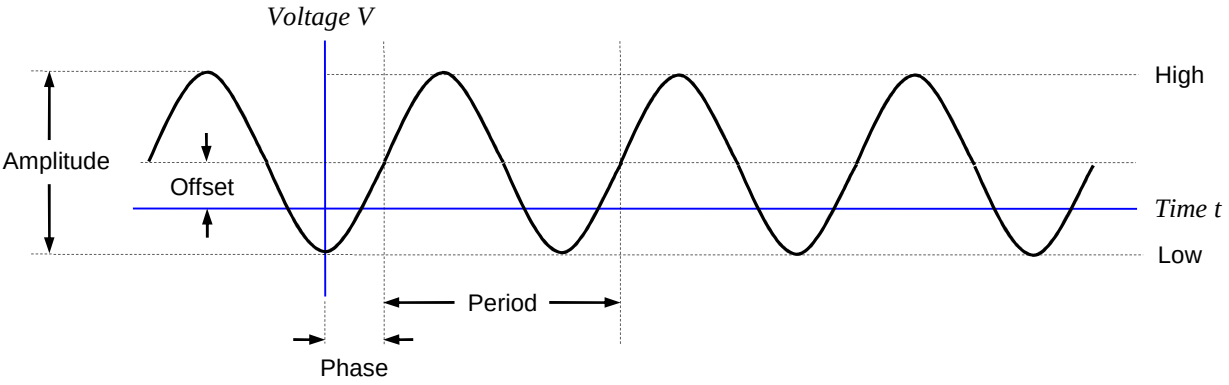


Figure 2: Characteristics of a periodic waveform (Tektronix terminology)

The amplitude of the waveform is the peak-to-peak variation[1] in voltage. The horizontal shift can be specified as a phase angle (in degrees).

The waveform's vertical characteristics (i.e., voltage) can be specified as an amplitude and offset, or as high and low levels.

Some useful conversion equations are:

$$Frequency = \frac{1}{Period} \qquad Amplitude = High - Low \qquad High = Offset + \frac{Amplitude}{2}$$

$$Period = \frac{1}{Frequency} \qquad Offset = \frac{High + Low}{2} \qquad Low = Offset - \frac{Amplitude}{2}$$

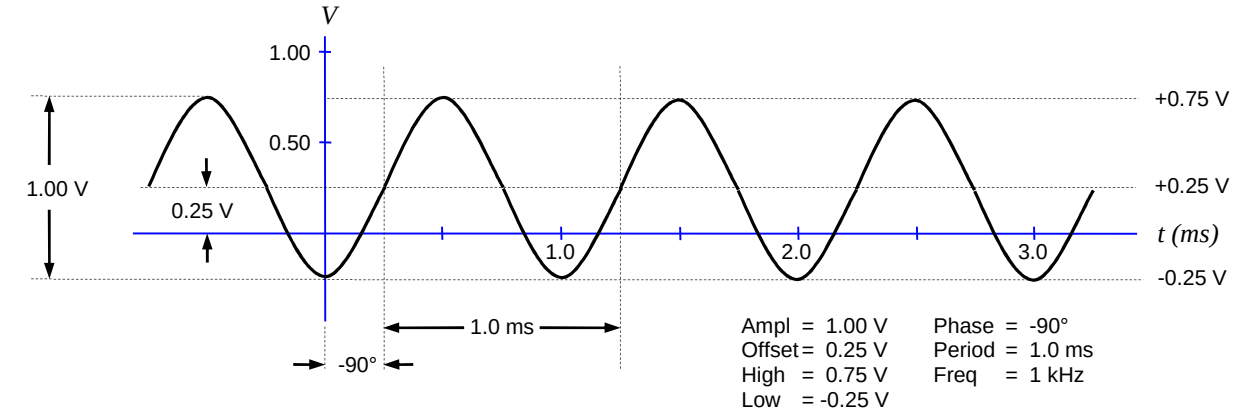


Figure 3: Example sinusoidal waveform with numeric values

[1] Math textbooks often define the amplitude as half the peak-to-peak variation. However, Tektronix assumes the amplitude is the full peak-to-peak value.

For a pulse train, the pulse duty cycle (in %) is defined as: $Duty = \frac{Pulse\ Width}{Pulse\ Period} \cdot 100$

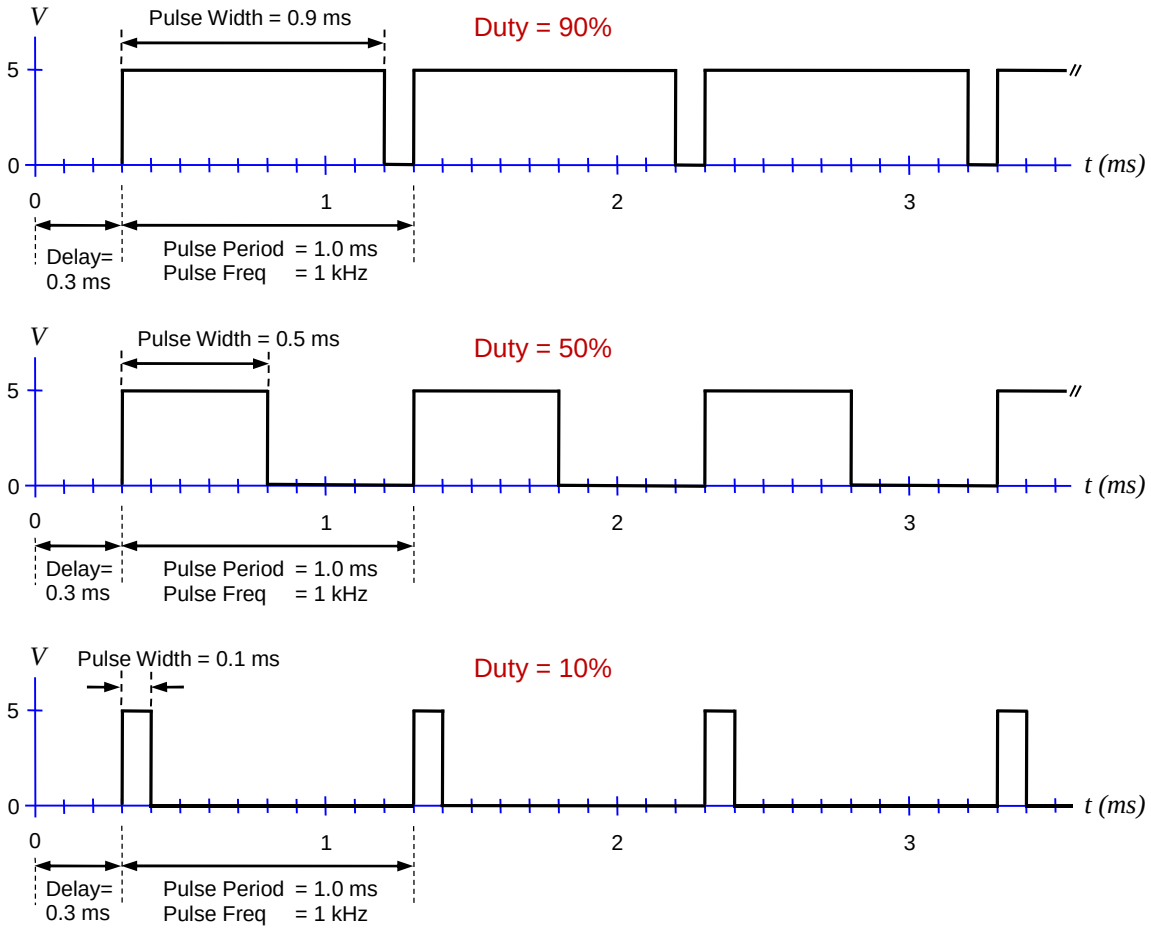
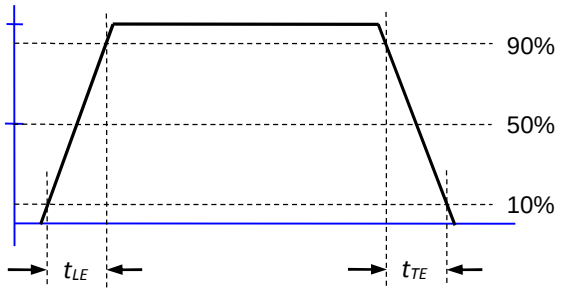


Figure 4: Examples of ideal pulse trains (Ampl = 5 V, Offset = 2.5 V or High = 5V, Low = 0 V)

Depending on the situation, a pulse's leading and trailing edge transition times may be relevant:



t_{LE} is the leading edge transition time.
t_{TE} is the trailing edge transition time.

The transition times are specified using the 10% and 90% amplitude points as references.

If t_{LE} and t_{TE} are a significant fraction of the total width, then the 50% amplitude point is a better reference for specifying the pulse width.

Figure 5: Edge transition widths for a realistic (non-ideal) pulse

4 – Instrument Front Panel

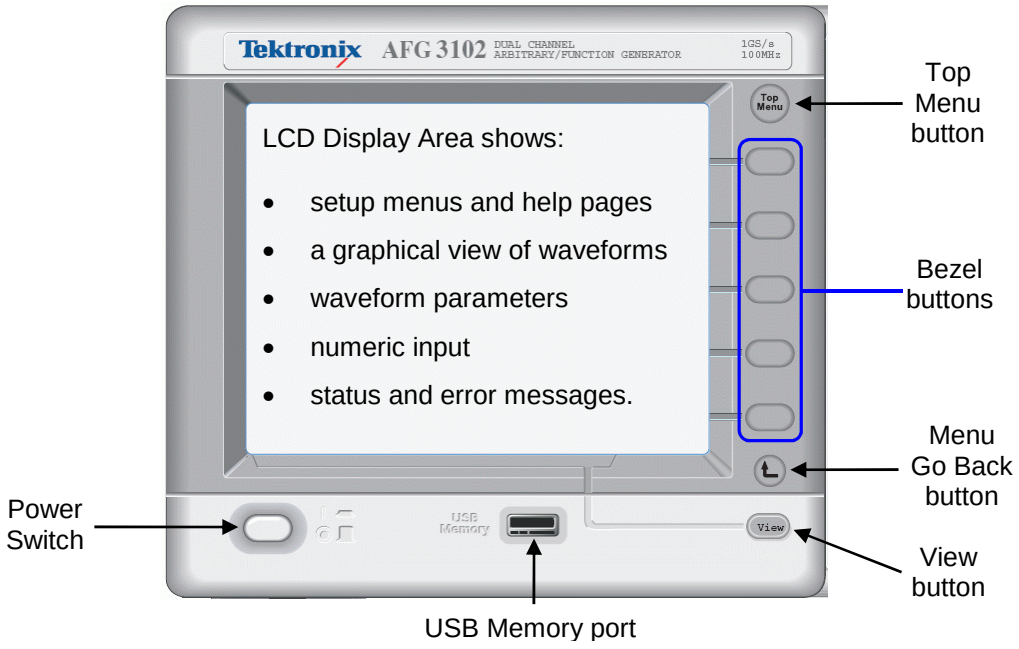


Figure 6: AFG3102 front panel detail view (left side) - Copyright © Tektronix, Inc.

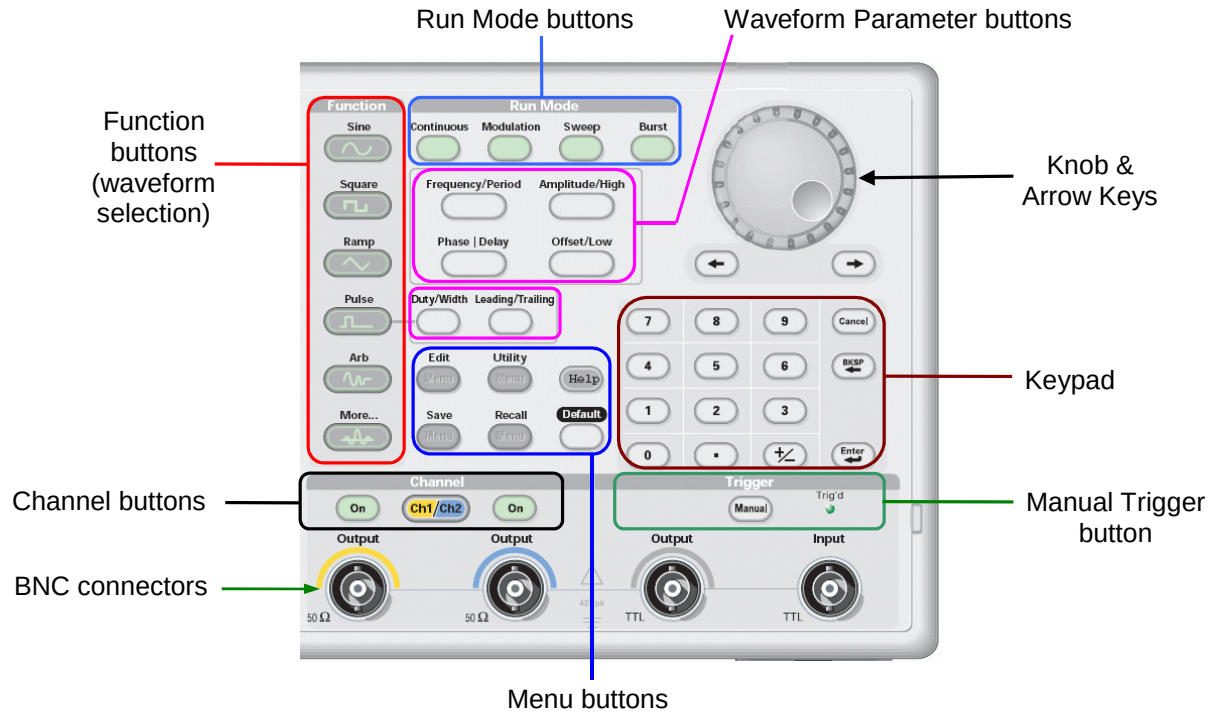


Figure 7: AFG3102 front panel detail view (right side) - Copyright © Tektronix, Inc.

► Instrument Power

Power Switch This turns the entire function generator either on or off.

► Interface Buttons

These buttons control the function generator's onscreen interface.

Top Menu The AFG3000 Series has a menu-based system for viewing or changing various instrument settings. The menus use a branching tree design, so this button returns to the top-most level of the menu tree.

Each press of this button goes back one level in the menu tree.

Bezel Bezel buttons are used to select bezel menu options that are displayed in an adjoining column on the LCD screen. The actions assigned to the five Bezel buttons depend on which menu is currently active.

View The function generator can display information on the LCD screen in several formats (waveform parameter and graph, graph comparison, and waveform parameter comparison). Each press of the View button toggles through the display formats.

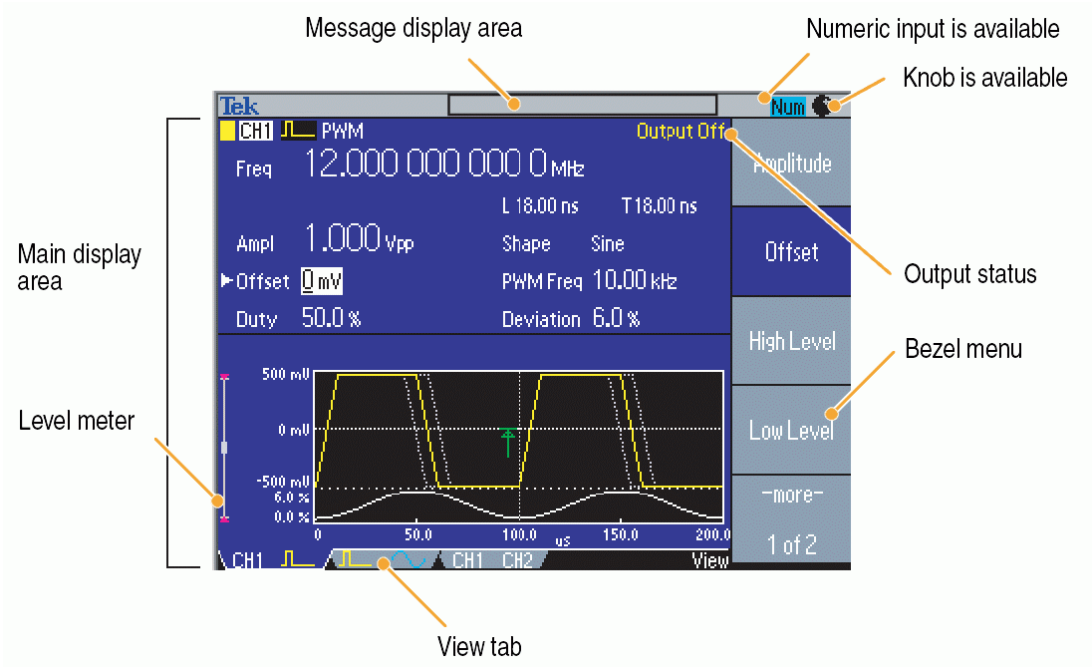


Figure 8: Sample AFG3102 onscreen interface - Copyright © Tektronix, Inc.

Note:

The LCD screen displays information for only one channel at a time. On a dual output function gnerator, use the [Ch1/Ch2] button to switch between the channels.

► Keypad

The keypad is used for entering or editing numeric values.

0 – 9 . Digit and decimal point buttons are used for numeric input.

+/– The +/– button toggles the sign of a number from positive to negative or from negative to positive.

Enter The Enter button completes entry of a value.

Cancel This cancels a pending action.

BKSP The backspace button is active during entry of a number. When pressed, it deletes the currently selected digit.

A waveform has multiple numeric parameters that define its characteristics. If a parameter is selected via a bezel button, the value becomes highlighted on the LCD screen. At that point, pushing any keypad button will activate the numeric input mode. A cursor indicates the currently selected digit.

In numeric input mode, the bezel menus show units that are appropriate for the value. By pressing one of the bezel buttons, the unit becomes attached to the number, and numeric input is completed.

Table 2: Some standard units available as bezel menus

Voltage	Freq	Time	Phase
V	MHz	s	°
mV	kHz	ms	
V_{PP}	Hz	µs	
mV_{PP}	mHz	ns	

► Knob and Arrow Keys

When entering or editing a numeric value, the left and right arrow keys move an underline cursor to select a specific digit within the number. The rotary knob can then be used to either increment or decrement the value of the selected digit.

Note: Using the knob and arrow keys is optional. Numbers can be entered directly with the keypad.

► Function Buttons

These buttons pick which waveform will be output on the currently selected channel. When pressed, the button becomes illuminated and the parameter menus for the waveform are displayed on the screen.

Sine Selects the sine waveform
{Frequency/Period/Phase, Amplitude/Level, Run Mode, Output}

Square Selects the square waveform
{Frequency/Period/Phase, Amplitude/Level, Run Mode, Output}

Ramp Selects the ramp waveform[2]
{Ramp Parameter, Frequency/Period/Phase, Amplitude/Level, Run Mode, Output}

Pulse Selects pulse waveform
{Pulse Parameter, Frequency/Period/Delay, Amplitude/Level, Run Mode, Output}

Arb Selects the user-defined arbitrary waveform
{Arb Waveform, Frequency/Period/Phase, Amplitude/Level, Run Mode, Output}

More … Displays options for choosing additional built-in waveforms.
{More Waveform, Frequency/Period/Phase, Amplitude/Level, Run Mode, Output}

► Waveform Parameter Buttons

These allow the user to bypass the bezel menus and immediately access common waveform parameters. Once selected, the parameter can be edited or changed using the keypad or knob.

Note:

The first press of a Waveform Parameter button selects the parameter. If pressed again, the parameter toggles between the pair of choices.

Frequency/Period Selects either Frequency or Period

Amplitude/High Selects either Amplitude or High

Offset/Low Selects either Offset or Low

Phase/Delay Selects either Phase (angle) or Delay (time)

Duty/Width Selects either Duty cycle (%) or Width (time) of a pulse

Leading/Trailing Selects either Leading edge or Trailing edge of a pulse

Note:

The Duty/Width and Leading/Trailing buttons only work when Pulse is the selected function.

[2] The AFG3000 Series does not have a function button dedicated to the triangle waveform. Instead, the Ramp Parameter bezel menu has three options for symmetry: 0% (rising ramp), 50% (triangle), and 100% (falling ramp)

► Run Mode Buttons

These control the operating mode of a waveform signal.

Continuous	Activates the continuous output signal mode (default)
Modulation	Activates the modulation mode and displays a parameter menu
Sweep	Activates the sweep mode and displays a parameter menu
Burst	Activates the burst mode and displays a parameter menu

► Menu Buttons

These buttons reveal menus for special function generator operations.

Edit	Edit menu is used for editing or creating user-defined waveforms.
Utility	Utility menu gives access to system utilities such as diagnostics.
Save	Save menu allows saving of new function generator setups to internal memory or an external USB memory device.
Recall	Recall menu allows recall of existing function generator setups from internal memory or an external USB memory device.
Help	Help accesses the built-in help documentation.
Default	The Default button restores the instrument's settings to their default values.

► Channel Buttons

CH1/CH2	The AFG3052C, 3102, and 3252 models have two output channels. Each channel can generate its own independent waveform. This button selects which channel's settings are selected for display or editing on the LCD screen. The AFG3021C model only has a single output channel, so the instrument does not have this button.
Channel [On]	Each channel has its own button for turning its output signal either on or off. When the output is in the "on" state, the button is illuminated.

► Manual Trigger Button

Manual	This button manually triggers the function generator to initiate a single sweep in Trigger Sweep mode.

► Output Connectors

The output signals from the function generator are available at the BNC connectors on the front panel. If a channel is currently disabled, the output signal is turned off at the corresponding BNC connector.

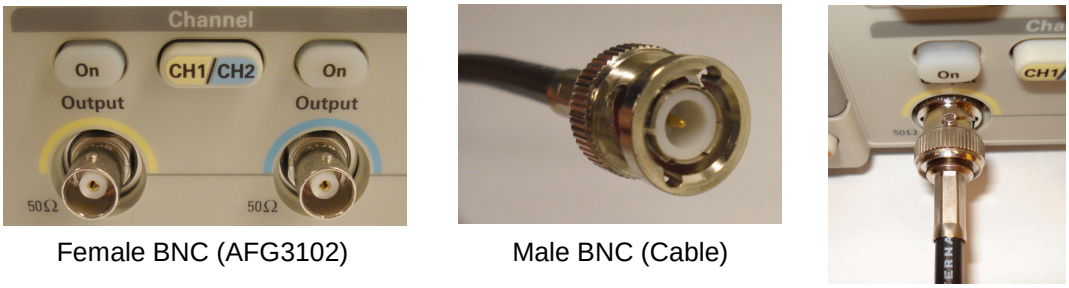
(Ch1 Output) Output connector for the Channel 1 waveform signal

(Ch2 Output) Output connector for the Channel 2 waveform signal

(Trigger Output) This connector outputs a TTL level pulse that is synchronized with the output from Channel 1. This can be used to trigger an attached instrument such as an oscilloscope.

Note:

The output impedance R_O of each channel is 50 Ω.



Female BNC (AFG3102) Male BNC (Cable)

Figure 9: BNC connections

7 – Standard Setup Procedure

1. Disable the channel outputs.
2. For each channel you intend to use:
    a. Select the channel (if needed)
    b. Select the desired function (e.g., sine, square, etc.)
    c. Adjust the waveform parameters using the Bezel buttons or Waveform Parameter buttons.
    d. Verify the parameter values to ensure the voltages and frequencies are within safety limits.
3. Enable the channel outputs.

8 – Examples

The Type codes are:

IB = Interface Button, BB = Bezel Button, FB = Function Button, CB = Channel Button, NK = Numeric Keypad

In Examples #1 and #2, assume the currently selected channel is Channel 1.

Example #1

Define a square waveform with the following properties:
Frequency = 1 MHz, High = 5 V, Low = 0 V

Two possible setups (either one would work):

Buttons to push	Type
Square	FB
Frequency/Period/Phase Menu	BB
Frequency	BB
1	NK
MHz	BB
↑	IB
Amplitude/Level Menu	BB
High Level	BB
5	NK
V	BB
Low Level	BB
0	NK
V	BB

Buttons to push	Type
Square	FB
Frequency/Period/Phase Menu	BB
Period	BB
1	NK
µs	BB
↑	IB
Amplitude/Level Menu	BB
Amplitude	BB
5	NK
V_{PP}	BB
Offset	BB
2.5	NK
V	BB

Example #2

Define a pulse waveform with the following properties:

Frequency = 1 MHz, Duty = 10%, High = 5 V, Low = 0 V, t_{LE} = 25 ns, t_{TE} = 15 ns

Two possible setups (either one would work):

Buttons to push	Type
Pulse	FB
Frequency/Period/Delay Menu	BB
Frequency	BB
1	NK
MHz	BB
↰	IB
Amplitude/Level Menu	BB
High Level	BB
5	NK
V	BB
Low Level	BB
0	NK
V	BB
↰	IB
Pulse Parameter Menu	BB
Duty	BB
10	NK
%	BB
Leading Edge	BB
25	NK
ns	BB
Trailing Edge	BB
15	NK
ns	BB

Buttons to push	Type
Pulse	FB
Frequency/Period/Delay Menu	BB
Period	BB
1	NK
µs	BB
↰	IB
Amplitude/Level Menu	BB
High Level	BB
5	NK
V	BB
Low Level	BB
0	NK
V	BB
↰	IB
Pulse Parameter Menu	BB
Width	BB
0.1	NK
µs	BB
Leading Edge	BB
25	NK
ns	BB
Trailing Edge	BB
15	NK
ns	BB

Example #3

For Channel 1, define a sine waveform with the following properties:
Frequency = 10 MHz, Amplitude = 2 V, Offset = 0.5 V, Phase = 0°.

For Channel 2, define a sine waveform with the following properties:
Period = 0.1 µs, High = 1.5 V, Low = -0.5 V, Phase = +45°.

Setup for Channel 1	
Buttons to push	**Type**
CH1/CH2[1]	CB
Sine	FB
Frequency/Period/Phase Menu	BB
Frequency	BB
10	NK
MHz	BB
Phase[2]	BB
0	NK
°	BB
↰	IB
Amplitude/Level Menu	BB
Amplitude	BB
2	NK
V_{PP}	BB
Offset	BB
0.5	NK
V	BB

[1]If necessary, push the CH1/CH2 button until Channel 1 is selected.

[2]The default phase is 0°, so it really isn't necessary to set it explicitly in this case.

Setup for Channel 2	
Buttons to push	**Type**
CH1/CH2[1]	CB
Sine	FB
Frequency/Period/Phase Menu	BB
Period	BB
0.1	NK
µs	BB
Phase	BB
45	NK
°	BB
↰	IB
Amplitude/Level Menu	BB
High Level	BB
1.5	NK
V	BB
Low Level	BB
-0.5	NK
V	BB

[1]If necessary, push the CH1/CH2 button until Channel 2 is selected.

In this example, the two signals are identical, except the Channel 2 waveform is shifted in phase with respect to the Channel 1 waveform.

9 – Output Voltage Amplitude

Suppose a load R_L is connected to an output channel on the function generator. The signal source has amplitude V_G. The generator's output impedance is R_O. Let V_O be the voltage present at the output terminals of the generator.

AFG3000 series:
R_O = 50 Ω

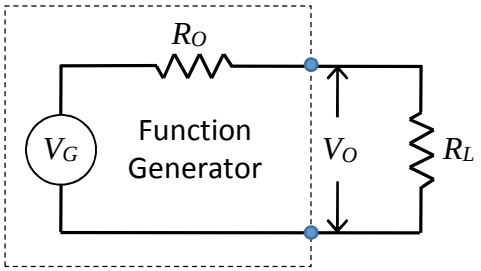


Figure 10: Load connected to output terminals of the function generator

Let V_{SET} be the amplitude value that the user sets on the front panel of the function generator. By default, the instrument *assumes* an impedance match (i.e., R_L is equal to R_O), so it automatically produces a V_G that is *twice* the value of V_{SET}, i.e., $V_G = 2V_{SET}$.

The value of V_O can be calculated by realizing that R_O and R_L form a voltage divider:

General solution for any value of R_L, when $V_G = 2V_{SET}$:

$$V_O = \left(\frac{R_L}{R_L + R_O}\right) V_G = \left(\frac{R_L}{R_L + R_O}\right)(2V_{SET}) = F \cdot V_{SET}, \text{ where } F = \frac{2R_L}{R_L + R_O}$$

∴ The output voltage V_O is a scaled version of V_{SET}. The scale factor F is between 0 and 2, inclusive.

Special case #1: $R_L = R_O$ (impedance is actually matched, i.e., R_L = 50 Ω) → F = 1, so $V_O = V_{SET}$

Implication: The voltage present at the generator's output terminals is equal to the set voltage.

Special case #2: $R_L \approx \infty$ (open circuit, i.e., no load attached) → $F \approx 2$, so $V_O = 2V_{SET}$

Implication: The voltage present at the generator's output terminals is twice the set voltage.

Note: To make the instrument generate an output voltage that corresponds to the desired set voltage when the load resistance is not 50 Ω, perform this procedure:

1. Press the *Top Menu* button on the front panel.
2. Select the *Output Menu* bezel button.
3. When the new menu appears, press the *Select Load Impedance* bezel button.
4. If R_L > 10k Ω, pick the *High Z* option. For R_L < 10k Ω, pick *Load* and enter the actual R_L value.

Example:

You connect a function generator with output impedance R_O = 50 Ω to a test circuit which has a load resistance of R_L. You configure the generator to output a sinusoid of amplitude V_{SET} = 1 $V_{p\text{-}p}$ at frequency f_{SET}. The voltage V_L across the load is monitored with an oscilloscope using a 1× probe. The oscilloscope has an input resistance of R_{in} = 1M Ω in parallel with an input capacitance of C_{in} = 15 pF.

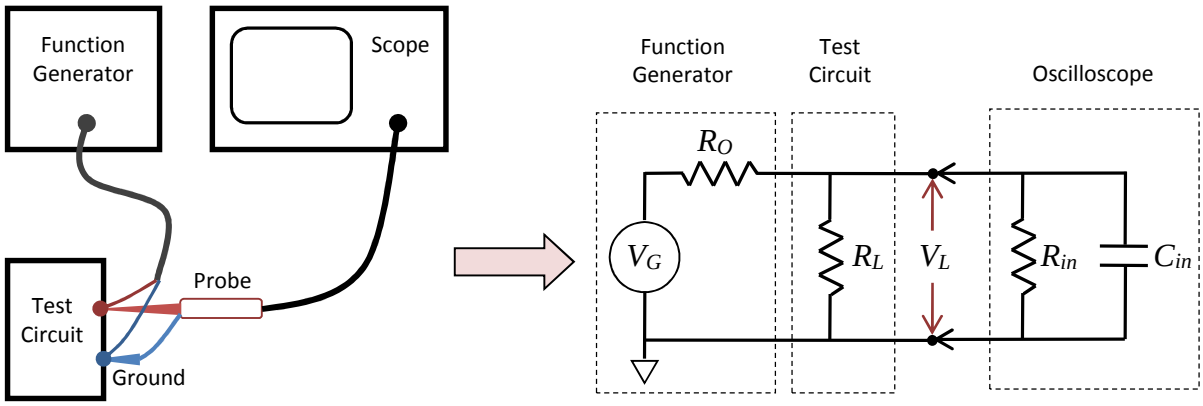


Figure 11: Example test circuit with oscilloscope

The function generator "sees" the load in parallel with the oscilloscope's input impedance:

$$Z_{EQ} = R_L \parallel R_{in} \parallel Z_{C_{in}} = \left(\frac{1}{R_L} + \frac{1}{R_{in}} + j\omega C_{in} \right)^{-1} = \frac{R_{in} R_L}{R_L + R_{in} + j\omega C_{in} R_{in} R_L} \quad \rightarrow \quad V_L = \left(\frac{2Z_{EQ}}{Z_{EQ} + R_O} \right) V_{SET}$$

Table 3: Calculated load voltage V_L versus load resistance R_L at specific signal frequencies f_{SET}
Given V_{SET} = 1 $V_{p\text{-}p}$, R_{in} = 1M Ω, C_{in} = 15 pF

R_L (Ω)	V_L (volts)				
	f_{SET} = 0 Hz (DC)	f_{SET} = 1 MHz	f_{SET} = 50 MHz	f_{SET} = 100 MHz	f_{SET} = 200 MHz
10	0.3333	0.3333	0.3331	0.3323	0.3293
50	1.0000	1.0000	0.9931	0.9733	0.9046
100	1.3333	1.3333	1.3171	1.2720	1.1290
500	1.8181	1.8181	1.7778	1.6712	1.3807
1000	1.9047	1.9047	1.8585	1.7377	1.4175
10K	1.9900	1.9899	1.9374	1.8017	1.4516
100K	1.9998	1.9998	1.9465	1.8090	1.4554

Appendix 1 – Technical Specifications

Table 4: Manufacturer's specifications

Model	**AFG3021B**	**AFG3052C**	**AFG3102**	**AFG3252**
Channels	1	2	2	2
Standard Waveforms	Sine, Square, Ramp, Triangle, Pulse, DC, Noise Sin(x)/x, Exponential Rise & Decay, Gaussian, Lorentz, Haversine			
Sine Waveform	1 µHz to 25 MHz	1 µHz to 50 MHz	1 µHz to 100 MHz	1 µHz to 240 MHz
Square Waveform	1 µHz to 12.5 MHz	1 µHz to 40 MHz	1 µHz to 50 MHz	1 µHz to 120 MHz
Rise/Fall Time	≤ 18 ns	≤ 7 ns	≤ 5 ns	≤ 2.5 ns
Jitter (RMS, typical)	500 ps	300 ps	200 ps	100 ps
Ramp Waveform	1 µHz to 250 kHz	1 µHz to 800 kHz	1 µHz to 1 MHz	1 µHz to 2.4 MHz
Pulse Waveform	1 mHz to 12.5 MHz	1 mHz to 40 MHz	1 mHz to 50 MHz	1 mHz to 120 MHz
Pulse Width	30.0 ns to 999.99 s	12.0 ns to 999.99 s	8.00 ns to 999.99 s	4.00 ns to 999.99 s
Resolution	10 ps or 5 digits			
Pulse Duty	0.001% to 99.999%			
Edge Transition Time	18 ns to 625 s	7 ns to 625 s	5 ns to 625 s	2.5 ns to 625 s
Overshoot (typical)	< 5%			
Jitter (RMS, typical)	500 ps	300 ps	200 ps	100 ps
Other Waveforms	1 µHz to 250 kHz	1 µHz to 800 kHz	1 µHz to 1 MHz	1 µHz to 2.4 MHz
Noise Bandwidth (-3 dB)	25 MHz White Gaussian	50 MHz White Gaussian	100 MHz White Gaussian	240 MHz White Gaussian
DC (into 50 Ω)	-5 V to +5 V	-5 V to +5 V	-5 V to +5 V	-2.5 V to +2.5 V
Arbitrary Waveforms	1 mHz to 12.5 MHz	1 mHz to 25 MHz	1 mHz to 50 MHz	1 mHz to 120 MHz
Effective Analog Bandwidth (-3 dB)	70 MHz	70 MHz	100 MHz	225 MHz
Sample Rate	2 to 128 K : 250 MS/s	2 to 16 K : 1 GS/s >16K - 128K : 250 MS/s	2 to 16 K : 1 GS/s >16K - 128K : 250 MS/s	2 to 16 K : 2 GS/s >16K - 128 K : 250 MS/s
Vertical Resolution	14 bits			
Rise Time/Fall Time	≤ 14 ns	≤ 10 ns	≤ 8 ns	≤ 3 ns
Jitter (RMS)	4 ns	1 ns at 1 GS/s 4 ns at 250 MS/s	1 ns at 1 GS/s 4 ns at 250 MS/s	500 ps at 2 GS/s 4 ns at 250 MS/s
Amplitude, 50 Ω load	10 mV_{p-p} to 10 V_{p-p}	10 mV_{p-p} to 10 V_{p-p}	20 mV_{p-p} to 10 V_{p-p}	50 mV_{p-p} to 5 V_{p-p}
Amplitude, Open Circuit	20 mV_{p-p} to 20 V_{p-p}	20 mV_{p-p} to 20 V_{p-p}	40 mV_{p-p} to 20 V_{p-p}	100 mV_{p-p} to 10 V_{p-p}
Accuracy	±(1% of setting + 1 mV) (1 kHz sine wave, 0 V offset, > 10 mV_{p-p} amplitude)			
Resolution	0.1 mV_{p-p} , 0.1 mV_{RMS} , 1 mV, 0.1 dBm , or 4 digits			
Units	V_{p-p} , V_{RMS} , dBm (sine wave only), V (high/low)			
Output Impedance	50 Ω			

Appendix 2 – References

[1] *Tektronix AFG3000 Series Data Sheet*, Tektronix, Inc.

[2] *Tektronix AFG3000 Series Arbitrary/Function Generators Quick Start User Manual (071-1631-03)*, Tektronix, Inc.

[3] *Tektronix AFG3000 Series Arbitrary/Function Generators Reference Manual (071-1639-03)*, Tektronix, Inc.